2.0 Summary of Methodology

The project, completed in early 2006, focused on certain common impacts that affect both community expenditures and aquatic life and streamflow. These factors are described below in Section 2.1. In Section 2.3, the study area is further described.

2.1 Targeted Development Impacts

Interference with the Natural Hydrologic Cycle. In a natural hydrologic cycle, a portion of the precipitation goes back into the atmosphere through evaporation and transpiration (evapotranspiration); a portion infiltrates into the ground, where it is able to recharge groundwater flows and provide baseflows for streams, and lastly a portion runs off over the surface of the land and is discharged into nearby surface waters. Figure 2-1 shows a simplified diagram of the hydrologic cycle.

Traditional development interferes with the natural hydrologic cycle. In urbanized areas, the three components (evapotranspiration, infiltration and runoff) still occur but in different proportions and with other factors coming into play. Increased imperviousness significantly increases runoff at the expense of infiltration. Water that once infiltrated through soils to recharge groundwater and replenish baseflows is converted into stormwater runoff. This runoff reaches streams in a matter of hours, as opposed to the several months it would take to reach the streams as recharge.

Infrastructure such as roads, bridges and pipelines may also be damaged as the bank erodes, setting the scene for potentially devastating damage during major floods.

Runoff is further increased as evapotranspiration is also converted to runoff when the original forested cover is removed. In addition, groundwater and surface water are withdrawn for human consumption. In some cases, much of this water consumption is returned to the ground as wastewater, but in other cases it is transferred from the area and discharged in other locations. Groundwater tables are lowered by the lack of infiltration/ recharge and in some cases the additional withdrawals to support the development, so that groundwater discharge to streams (baseflow) may eventually suffer during dry periods. Figure 2-2 shows a simplified diagram of the hydrologic cycle under developed conditions.

Reduced Recharge.

Reduced recharge to groundwater is one of the greatest impacts of development. Recharge is essential to replenish groundwater aquifers, rivers and streams. Without adequate recharge, water supply wells can dry up and/or their yield can be significantly reduced. Rivers and streams can also dry up as groundwater tables are lowered, reducing groundwater baseflows. This is particularly true in the summer when there is less rainfall to supply rivers and streams. The reduced groundwater baseflows also mean higher stream temperatures and greater pollutant concentrations, as more of the streamflow comes from surface runoff that has heated and picked up pollutants as it traveled over dark, impervious surfaces such as pavement and rooftops.

Flooding. Increased runoff equals increased flooding, which can lead to erosion of natural streambanks and widening of the stream channel to handle the larger flow volumes during frequent storm events. This increases sediment loadings to the streams and exposes plant roots along the banks. Although flood controls such as detention basins have been used for many years to reduce peak flows, they only address the larger infrequent storms, typically those above the 2-year, 24-hour storm. Meanwhile, stream channels are exposed to more frequent erosive flows associated with the smaller storms, resulting in loss of bottom dwelling and other aquatic organisms that rely on relatively stable, sediment-free habitat. Infrastructure such as roads, bridges and pipelines may also be damaged as the bank erodes, setting up the scene for potentially devastating damage during major floods.

Increased Water Temperature. Impervious surfaces also increase stream temperatures. Stormwater runoff is warmed as it travels over hot surfaces such as black pavement and rooftops. This heated surface runoff replaces much of the cool baseflow that reached the stream under natural, undeveloped conditions. This effect is then exacerbated by clearing of trees along streams, eliminating shade needed to keep streams cool. The increased temperatures can reduce dissolved oxygen levels, necessary for fish and other aquatic life to survive. This may lead to the replacement of sensitive fish species and other life forms with organisms that are better adapted to poorer conditions.

Higher Pollutant Loads. Pollutant concentrations also increase with increased runoff. As human land use intensifies, pollutants build up (i.e., pesticides, fertilizers, animal wastes, oil, grease, heavy metals, suspended solids, phosphorus, pathogenic bacteria and road salt). These materials are then washed off by rain and runoff, increasing the pollutant load to receiving waters. Not only does this impact rivers and streams by reducing sensitive species and increasing more tolerant species, but it also impacts receiving lakes and ponds. Increased phosphorus loads to lakes and ponds can cause eutrophication, which increases aquatic vegetation and filling in of the water body. Pathogenic bacteria can lead to beach closures, more costly treatment requirements for surface water supplies and closure of shellfish beds.

Each of these impacts must be controlled to sustain a healthy water balance and environment, and were considered in the development of an EOD for Lancaster. The term ‘water balance’ as used in this report refers to the inflows (i.e., recharge, wastewater inputs) and outflows (i.e., water supply withdrawals, off-site wastewater transfers) to the study area to determine the total net effect on groundwater and baseflow contributions. The purpose of the EOD is to maintain the existing water balance as much as possible, by properly planning for growth.

2.2 Study Area Subwatersheds

In a natural hydrologic cycle, groundwater generally flows towards rivers and streams, since, like surface water, it is subject to gravity and flows downhill. Once reaching a stream or river, the groundwater discharges (as long as it is at a higher elevation than the river), and thus provides baseflow that keeps streams flowing during the dry summer months. As water tables decline due to reduced recharge and increased withdrawals, streams may instead begin discharging to groundwater, losing even more flow. The intensity of this problem is dependent on local conditions such as geology, drainage area and level of development. Larger streams will have a less visible impact than smaller, headwater streams due to their large contributing area.

Considering this factor along with varied land uses within the study area, the evaluation used subwatershed scale evaluations of the hydrologic balance rather than focusing on the largest downstream water body. This allows for evaluations and impacts to headwater streams, as well as the larger receiving streams and provides a more manageable scale to evaluate the study area. This provides more localized information on which to base decisions

Lancaster was divided into 9 subwatersheds to evaluate development impacts and the local water budget for each area. The subwatershed boundaries are natural boundaries dictated by the local topography. These boundaries generally follow ridgelines or high points and represent the area that drains to the furthest downgradient point, which was typically chosen where a stream intersected another stream. Since Lancaster does not have jurisdiction in other towns or the Fort Devens military reserve, these boundaries were also used to delineate subwatersheds, even though the natural topographic boundary may extend into adjacent towns and Fort Devens. Since the water balance is focusing on keeping the water that falls within Lancaster in the Town, rather than on actual streamflows, this method of delineation was appropriate.

Most water bodies within Lancaster drain to the North Nashua and Nashua Rivers. The subwatershed divisions were chosen to represent each of the major tributaries draining to the North Nashua and Nashua Rivers, as well as those water bodies that drain out of town. Figure 2-3 shows the subwatershed divisions. The names and sizes of each subwatershed are listed below:

Subwatershed Name	Area (acres)
Shaker Hill	575
Fort Pond	1089
Spectacle Pond	460
McGovern Brook	767
White Pond	399
North Nashua River	1674
Wekepeke Brook	1315
Ballard Hill	1190
Nashua River	877

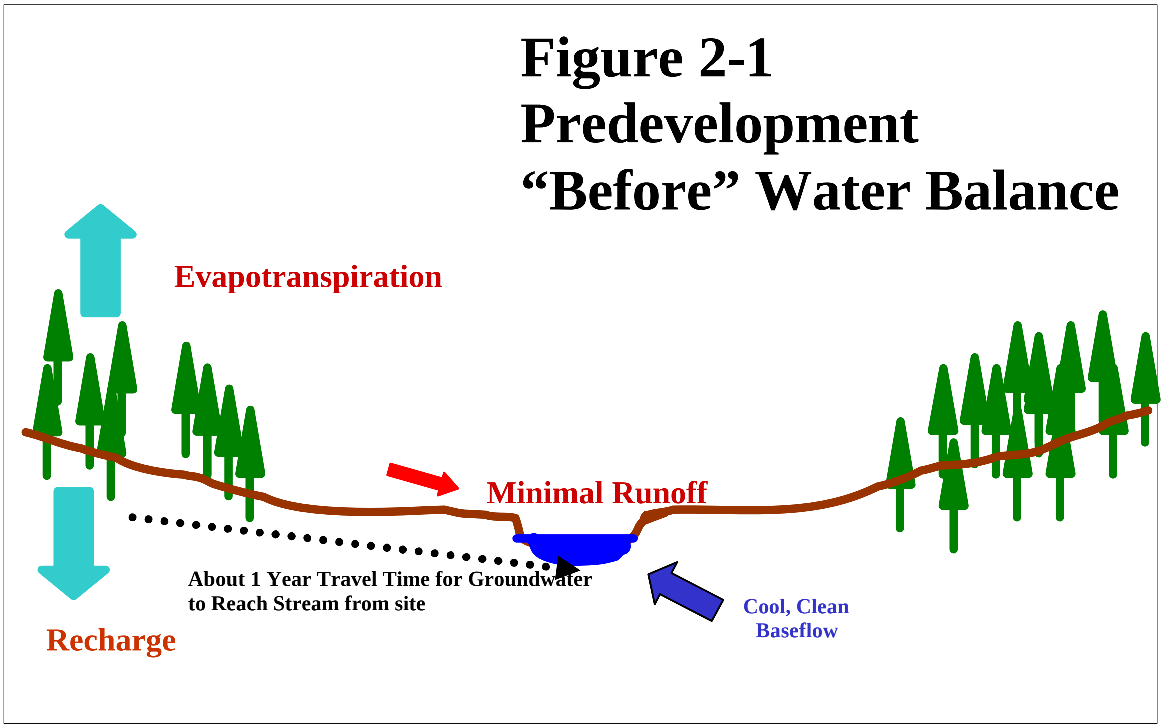


Figure 2-1
Predevelopment
“Before” Water Balance
Evapotranspiration
Minimal Runoff
About 1 Year Travel Time for Groundwater
to Reach Stream from site
Cool, Clean
Baseflow
Recharge

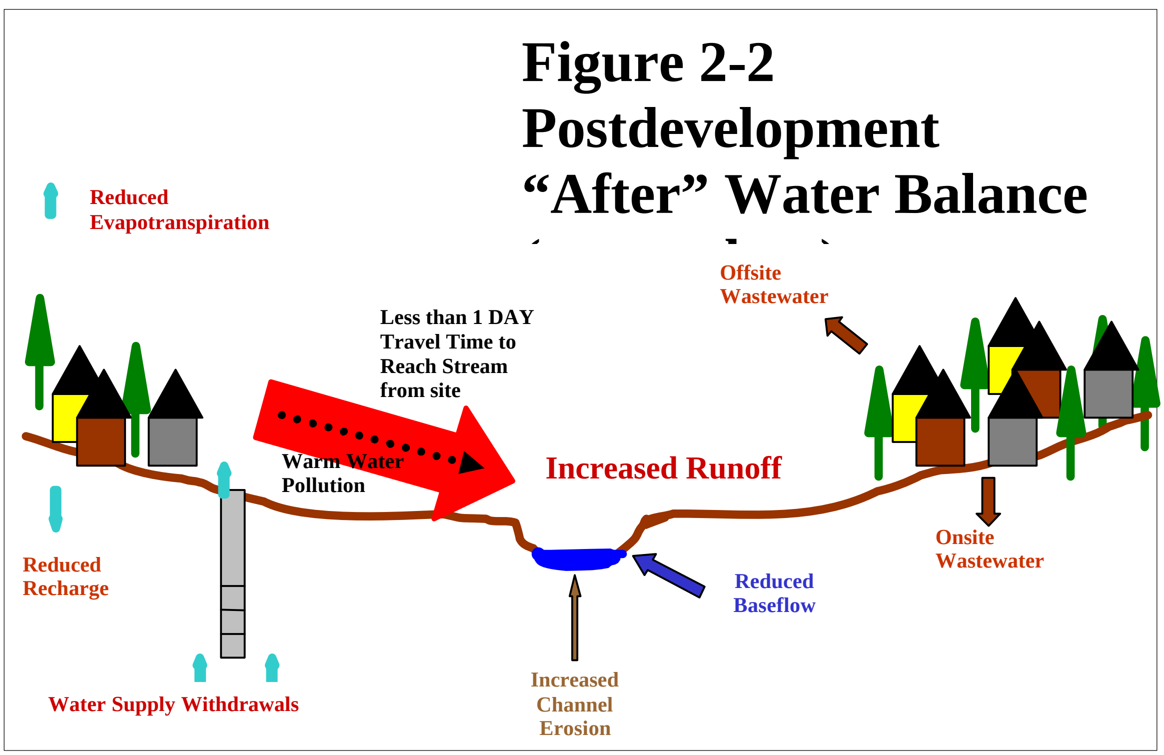
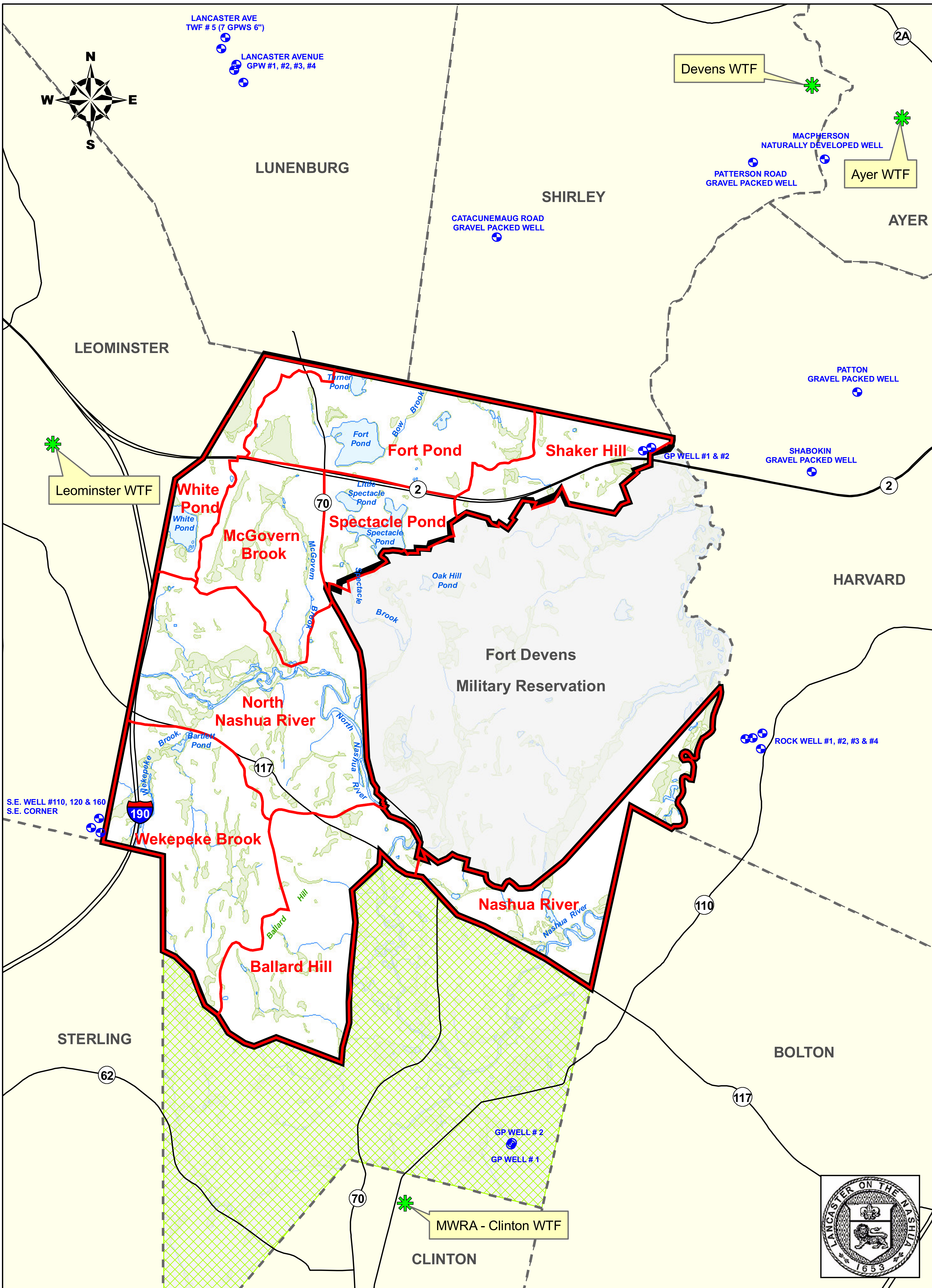


Figure 2-2
Postdevelopment
“After” Water Balance
Reduced
Evapotranspiration
Offsite
Wastewater
Less than 1 DAY
Travel Time to
Reach Stream
from site
Warm Water
Pollution
Increased Runoff
Reduced
Recharge
Onsite
Wastewater
Reduced
Baseflow
Water Supply Withdrawals
Increased
Channel
Erosion



LEGEND

IWRM Study Area
Subwatershed Boundaries
Sewer District
Public Water Supply
Wastewater Treatment Facility

Hydrography
Lake, Pond
DEP wetlands
Stream, Brook

Data Sources: Town of Lancaster, MassGIS, CEI

0 2,500 5,000 7,500 10,000 Feet

Figure 2-3

Study Area Locus

Lancaster, MA

Comprehensive Environmental Inc.